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## FINAL REPORT EMERGENCY EARTH ORBITAL ESCAPE DEVICE STUDY

### VOLUME 1: CONDENSED SUMMARY

(NASA-CR-99542) EMERGENCY EARTH ORBITAL  
ESCAPE DEVICE STUDY. VOLUME 1: CONDENSED  
SUMMARY (Lockheed Missiles and Space Co.)

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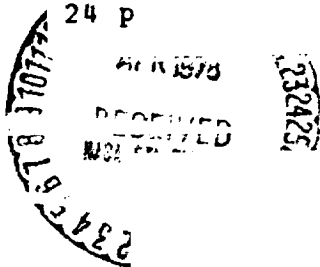
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## **EMERGENCY EARTH ORBITAL ESCAPE DEVICE**

### **Volume 1 Condensed Summary**

This document is the final report for the "Emergency Earth Orbital Escape Device Study" that was completed by Lockheed Missiles & Space Company for the National Aeronautics and Space Administration, under Contract NAS9-7907.

The final report has been prepared in volumes as follows:

- Volume 1 Condensed Summary.
- Volume 2 General Technical Summary
- Volume 2A Systems Requirements and Concepts
- Volume 2B Spacecraft System Design
- Volume 2C Reentry Controls
- Volume 2D Environmental Control, Communications, and Electrical Systems
- Volume 2E Additional Study of Tasks
- Volume 3 Preliminary Program Definition Plan
- Volume 4 Apollo Applications Program Emergency Escape System  
Preliminary Program Definition Plan

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## CONDENSED SUMMARY

### 1. INTRODUCTION

The objective of the present study, performed by LMSC under contract to and in close cooperation with the Manned Spacecraft Center, was to conduct parametric analyses of various escape devices with emphasis on a three-man, single purpose escape system; to accomplish conceptual design of the recommended approaches; and to generate gross costs and schedules for preliminary program definition planning purposes. This objective has been achieved in the course of the study reported on here. In performing the study, Lockheed used a systems approach to identify and define critical requirements and tradeoff criteria and to develop an optimum state-of-the-art design. Guidelines were first agreed upon between Lockheed and the Manned Spacecraft Center, based on operational considerations and on data gathered in earlier studies. Operations analyses and tradeoff studies then enabled refinement of these guidelines and the translation of them into system requirements. These system requirements provided the basis for selection of a recommended configuration and concept from which to proceed to design definition. After review and discussion of the proposed system requirements and recommended concept by the Manned Spacecraft Center, Lockheed then proceeded with design definition, based on state-of-the-art technology and provision for use, where practicable, of existing, proven components.

The resulting conceptual design, as described in Volumes 1 and 2 of this report, represents a concept meeting the basic study objectives for a three-man escape device for use in low earth orbits.

Additional study tasks also discussed include: description of the modification necessary to adapt the device for synchronous escape and return and the feasibility of scaling up the basic escape vehicle to accommodate a six to nine man crew.

## 2. STUDY OBJECTIVES

The objectives of the EEOED study are to conduct and document parametric analysis of various feasible earth orbit return devices and to accomplish conceptual designs of the recommended approaches. A Preliminary Program Definition Plan, including gross costs and schedules, has been prepared and is documented as a separate volume of this report.

## 3. RELATIONSHIP TO OTHER NASA EFFORTS

The primary effort expended on the EEOED study was directed toward the preliminary design and systems engineering definition of a three-man orbited escape device.

Work previously completed by NASA agencies and contractors in the areas of orbital escape which were utilized in the EEOED study include: NASA-MSC Orbital Escape System Status Report, dated 1967 April 27; Study of Manned Flight Emergency Concepts (NASW 1561) by the Aerospace Corporation; and Advanced Logistics Spacecraft System (NAS 9-6801) McDonnell Astronautics Company. In the development of storage concepts used in the EEOED study, the Boeing Company study titled; Saturn V Single Launch Space Station and Observatory Facility (NAS 9-6816), and NASA-MSC study MSC-EA-R-66-1, Preliminary Technical Data for Earth Orbiting Space Station were used as was existing engineering data on Apollo Applications Program projected mission.

#### 4. METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

The initial concept was an escape device to accommodate one, two, or three men for emergency return from low earth orbit. The study approach, guidelines, and plan are presented in the following sections.

##### 4.1 DESIGN GOALS AND PHILOSOPHY

The basic goal was to provide a design as light and small as possible which would have long storage life and quick reaction time. To meet these goals, passive systems were to be used as much as possible.

Inherent in the concept of quick reaction time is the ability to accommodate the astronauts in an "as-is" condition, i.e., shirtsleeves to pressurized suits. Although the parachute is the analogy that first comes to mind when speaking of an emergency orbital escape device, the quick reaction "as-is" concept is more analogous to the supersonic ejection capsule with complete self-contained systems held in a constant state of readiness.

Actually, when consideration for injured or incapacitated crewman is included, the most desirable device is akin to an elevator where any number can enter in various states, one man closes the door and initiates the descent (separation and retrofire) and no further crew participation is required until after landing. However, as with the elevator, survival of the occupants is the paramount consideration.

The desirable characteristics are then crew safety, minimum crew participation, long storage life, and quick reaction time. In order to meet the last two, crew participation cannot be replaced by electronic-mechanical systems which have to be held in an active condition or require long warm-up times. Consequently, the basic design philosophy was to provide a manually controlled separation and retro maneuver using visual

references and aerodynamic stability for passive attitude control during reentry. Similarly, the shape would provide upright flotation stability without the use of auxiliary devices. Two basic assumptions were necessary for this approach:

- That an astronaut could successfully complete the retro maneuver using manual control and visual references
- That the two stability criteria were not incompatible and could be met with the same configuration within crew packaging constraints and without excessive size or weight penalties.

Additional design considerations were to use existing state-of-the-art subsystem components and materials.

## 4.2 GROUND RULES AND GUIDELINES

The initial guidelines and ground rules, provided by NASA, were subsequently reviewed and jointly modified by initial studies. The results are presented in four sections: Orbit, Operations, Crew System, and Design.

### 4.2.1 Orbit

- Altitude Range. The escape device will be designed to effect reentry and recovery from circular orbits only at an orbit altitude range of 100 to 300 nm.
- Orbit Inclination. The host space station orbit inclination will be from 28 to 90 deg.

### 4.2.2 Operations

- Landing Sites. Water landing only will be considered.
- Landing Latitudes. The nominal landing site will be between the equator and the northern latitude water areas in which the minimum water temperature will be no less than 70°F.

- Landing Footprint. The desired landing footprint will be 100 x 200 nm. If dispersion analysis shows that those limits will be exceeded, the causes will be identified.
- Postlanding Support. The escape device minimum flotation time will be 24 hr including an allowance of 12 hr for nighttime.
- Night Recovery. Nighttime recovery operations will be avoided.
- Communications. A two-way voice communication capability will be provided for ground contact while the escape device is in orbit. Recognizing that this link could fail, a supplementary orbital beacon can be provided that has the capability of transmitting the time of escape device retro to the ground.
- Orbit Fly Time. A maximum capability of 12 hr on-orbit loiter time will be provided including a 3-hr allowance to provide for ground contact on the two-way communications link.

#### 4.2.3 Crew System

- Station Pressure. A nominal station pressure of 7.5 psi is assumed. The escape device nominal pressure will be 5.0 psi, single gas supply.
- Escape Device Ambient Condition. The escape device will provide a shirt-sleeve environment for one, two, or three astronauts. Access clearances will provide for A5L or A7 pressurized suits. The life support system will not provide for pressure suits. Means will be provided for removal of suits immediately after the separation rotational dispersions have been removed.
- Escape Device Control. It is assumed that at least one astronaut will be functional and able to operate the escape device up to aerodynamic entry. Whenever practical, manual controls will be provided in preference to electronic and/or feedback control loops.
- Escape Device Sizing. Clearances, dimensions, sizes, etc., will be based on the suited dimensions of the 54 astronauts as of 1 May 1968.

#### 4.2.4 Design

- Single Purpose Usage. The escape device will be used only in the event the host vehicle fails, escape is necessary, and no other means exists for the crew to return to earth.
- Parasitic to Host Vehicle. The host vehicle will supply the escape device with power, replenishment gases or liquids, and spare parts for maintenance or repair.
- Power. Batteries only will be considered for power. The escape device will be operationally ready for use at all times.
- Stability. The escape device will have single point aerodynamic and flotation stability. It will right itself if it is either reentering aft-end first or if a move should turn the device upside down.
- Lifetime. The design will provide for 5-yr on-orbit storage lifetime.
- Interfaces. The interface attachment structure will be compatible with any one of the following: (1) AAP SIV-B Wet Workshop, (2) Saturn V Single Launch Space Station, (3) Rotating I Space Station
- Host Vehicle Damage. Operation of the separation mechanism will not damage the host vehicle.
- Body Shape. The escape device structural shape will be a symmetrical body of revolution and will have zero lift.
- Chutes. Standard Apollo-type ring-sail chutes will be used and sized for the escape device design.
- Recovery Aids. Recovery aids will consist of a recovery beacon for on-water operation, a flashing light, and a minimum "Care" package.

#### 4.3 STUDY PLAN

The study consisted of the following three phases:

- Requirements and Concept Definition and Recommendation
- Recommended Concept Design Definition
- Preliminary Program Definition Plan and Final Reports

Using the initial guidelines and groundrules as a starting point, analyses were performed to determine operation and crew requirements. Preliminary performance and design concept studies were performed to define system design requirements and provide performance data for subsystem trade studies. Configuration and subsystem concepts were derived to satisfy the requirements. The various concepts were evaluated and a selected concept recommended to the NASA at a midterm presentation.

During the second phase, the selected concept was further defined by configuration and subsystem design studies. The performance of the resulting configuration was determined for both aerodynamic and flotation stability. The performance requirements for a synchronous return mission and a six-nine man escape vehicle were determined and compared with the recommended design.

The final phase was the preparation of a Preliminary Program Definition Plan for the design, including schedules and cost estimates to provide a basis for future NASA planning. In addition, final presentations and reports were completed in this phase.

## 5. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The escape system design depicted in Fig. 5-1 will safely return one, two, or three astronauts to designated splashdown areas from low earth orbit under emergency conditions. The forward heatshield end is a 80-deg cone. The aft end is a 60-deg cone and contains the 40-in. diameter entry hatch. A retro/RCS module is located at the forward heatshield end of the escape vehicle. This module contains four solid motor retrorocket motors and the hydrazine monopropellant reaction control thrusters. This module is separated at approximately 400,000-ft altitude.

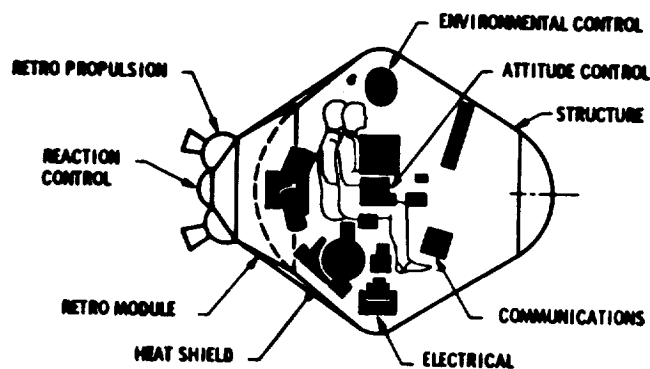


Fig. 5-1 General EEOED Configuration

### 5.1 SYSTEM REQUIREMENTS

Operational. The EEOED is designed to be used for escape from orbits of 28 to 90 deg inclination and circular altitudes of 100 to 300 nm. The 12-hr loiter time allows selection of autonomous or ground-directed sequences and a water landing area (minimum temperature, 70°F) within 1800 nm of one of the five permanent air/sea rescue bases. The device is designed for water landing only and provides a minimum of 24-hr operation of the ECS and communications equipment on the surface. This provides sufficient time to delay recovery operations until daylight in the event of a nighttime landing.



Aerodynamic. The device is designed for a pure ballistic reentry (no lifting) and to have single-point stability, i.e., the shape is such that the capsule will orient itself to the heat shield forward attitude even in the event of a tail-first attitude at 400,000 ft.

Flotation. The flotation characteristics assure that the capsule will float in the nose-down attitude and will return to this position even if overturned by wave action or landing velocities.

Crew System. The design will accommodate and operate with one, two, or three men. Ingress may be suited or unsuited. Provisions are made to remove suits after parent vehicle separation and before reentry. The crew is positioned with their backs to the heatshield so that the acceleration vector will be normal to the eye-heart line.

## 5.2 CONFIGURATION SELECTION CRITERIA

The interaction between the mandatory requirements and the constraining factors prescribe the external geometry of the EEOED. The sphere results in the smallest size after fitting in the crew, but the center of pressure and the metacenter are located at the center of the sphere. The only way to meet the stability criteria is by placing the c.g. towards the nose. However, the major component for c.g. determination is the crew envelope which also is located at the center.

By modifying the sphere with flanges, the center of pressure can be influenced to improve single-point aerodynamic stability, but the metacenter remains the same.

By the use of sphere-cone shapes for the fore and aft ends, the center of pressure and the metacenter can both be manipulated and more room is available for equipment and crew location. Since the stability requirements for the forward and aft ends are essentially opposite, i.e., stable in one direction and unstable in the opposite, both ends can be optimized by making the shape of each fit its own criteria. This procedure results in a configuration of two dissimilar sphere-cones.

### 5.3 SPHERE-CONE PARAMETERS

Based on the preliminary configuration results, a capsule of 3000 lb and 100-in. diameter was selected for detailed analysis. A key guideline for static stability, both aerodynamic and flotation, is the distance of the center of pressure and the metacenter from the nose. Stability increases as these two points move aft. In designing the aft part of the capsule, two additional constraints were overriding. Aerodynamics limited cone angle to no less than 60 deg to prevent possibility of flow attachment and reattachment while the geometry for a 40-in. hatch dictated a radius of 24 inches. In addition the 60/deg/24-in. radius provides additional room for accommodating suit removal.

### 5.4 BASIC DIMENSIONS – SELECTED CONFIGURATION

Basic dimensions for the conical shape chosen for the EEOED and shown in Fig. 5-2 mission were developed from the basic 80-deg and 60-deg cone angles combined with a 100.0 in. maximum diameter. The apex of the 80-deg cone was established as Station 100.0 and all longitudinal points on the vehicle are taken from there. The fore and aft cone radii of 35.0 and 26.5 in. respectively are tangent to the cone and are full spherical radii. Total calculated length of the EEOED, Station 119.4 to Station 218.8, is 99.4 in.

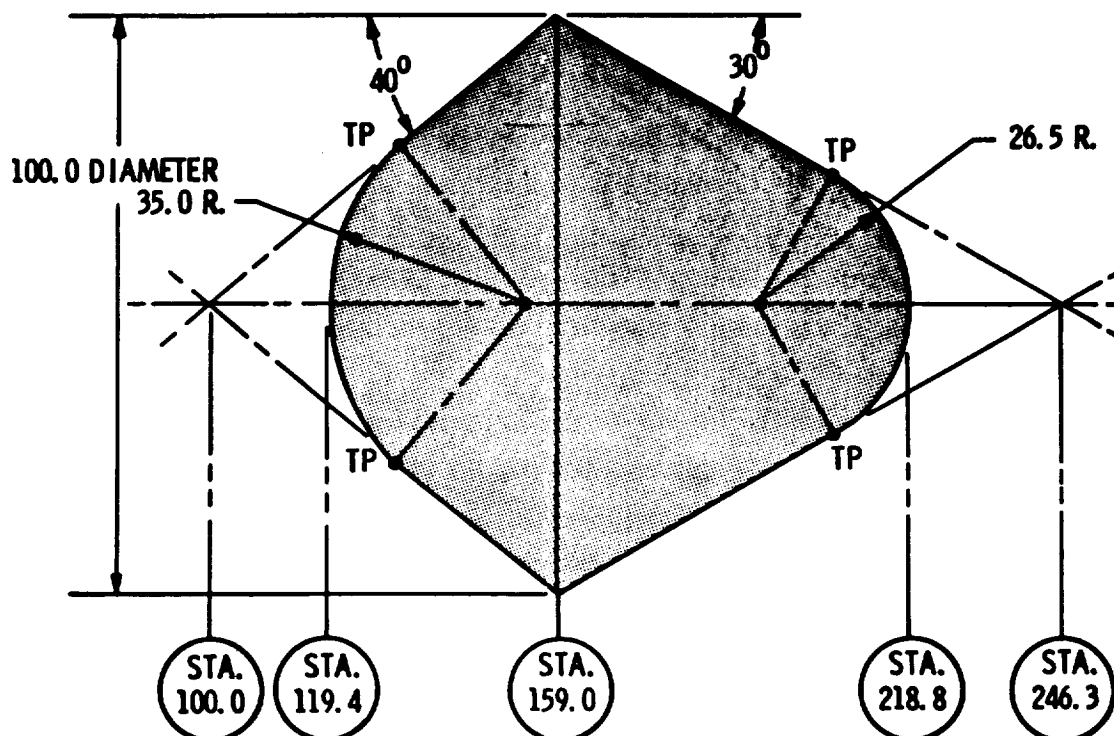


Fig. 5-2 Basic Dimension, EEOED

## 5.5 ESTIMATED MASS PROPERTIES

The ascent/storage weight of 2769 lb represents the weights of all EEOED subsystems, including expendables, and is the launch configuration. A weight of 242 lb for each suited crewman is assumed, giving a total of 726 lb for the three-man crew.

Center-of-gravity calculations show an aft c.g. shift of 0.6 in. at reentry for a two-man configuration and an aft shift of 0.1 in. for a one-man crew.

Weight changes during the various mission phases include the environmental control system consumables and ejection of the orbiting beacon during the orbital loiter period; RCS and retro propellants burned during retrofire; separation of the retro module prior to reentry; ablator burnoff; and separation of the main parachute after landing. A tabulation of the estimated EEOED weights on center-of-gravity for the mission phases is shown in Fig. 5-3.

DESCRIPTION	WEIGHT (LB)	CG (IN.)		
		X	Y	Z
ASCENT/STORAGE	2769.0	28.6	1.5	0.0
SEPARATION-3 MEN	3495.0	29.6	1.2	0.0
START OF RETRO	3467.0	28.5	1.1	0.0
RETRO BURNOUT	3146.0	33.5	1.2	0.0
REENTRY	3020.0	35.6	1.3	0.0
MAIN CHUTE DEPLOYMENT	2964.0	36.2	1.3	0.0
SPLASH DOWN	2794.0	34.2	2.7	-0.2

Fig. 5-3 Estimated Mass Properties

## 5.6 EQUIPMENT WEIGHT

Figure 5-4 presents a tabulation of major system equipment and corresponding weights for a 12-hour orbit and 24-hour wait time after splashdown. A retro velocity of 600 ft/sec and a total reaction control impulse of 5,000 lb-sec were also assumed. Not included are the weights of the individual crewmen or their pressure suits.

<u>Equipment</u>	<u>Weight (lb)</u>
Structure	1479
Chute Subsystem	150
Retro Propulsion	295
Reaction Control	51
Attitude Control	8
Electrical	225
Communications	52
Environmental Control	<u>364</u>
Total System Weight	2624

Fig. 5-4 Equipment Weight

## 5.7 SEQUENCE OF EVENTS

Hatch closure will enable the EEOED safe-arm circuit and will initiate the escape mission, with activation of the environmental control and reaction control systems occurring prior to separation of the EEOED from the station. After separation, any rotational rates will be damped out through manual control of the reaction control thrusters, pressure suits will be removed and stowed, voice contact with ground station will be made, and retro fire time established. Manual control of the vehicle will be used to orient the vehicle to the desired retro attitude, and retrofire will be initiated by actuation of the retrofire switch located on the attitude hand controller. Initiation of retrofire will also command separation of the orbiting beacon. Retro attitude will be maintained, manually, throughout retrofire to approximately 400,000 ft. At this time—determined from the elapsed time on the retro-timer clock—the reentry angle will be set and the retro module jettisoned. Deployment and separation of the drogue and main parachute systems will be initiated by signal from the recovery timer; however, manual backup switches located on the control panel will be installed for each of the functions. Following impact, the main parachute will be separated from the vehicle, the beacon light activated, surface location aids deployed, and the postlanding exhaust fan turned on. Power to all systems, except the fan, VHF beacon, and flashing light will be shut down at this time. The sequence is pictorially described in Fig. 5-5.

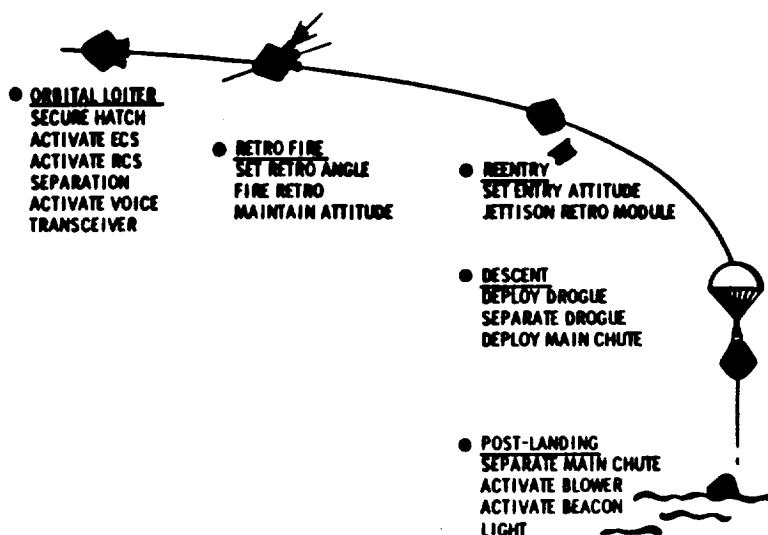


Fig. 5-5 Sequence of Events

## 5.8 DESIGN TRAJECTORY

A reentry trajectory from 300 nm has been determined by a 6-D computer program utilizing the mass properties and aerodynamic coefficients of the selected configuration. The design trajectory reflects a maximum oscillatory acceleration on the brain of  $\pm 1g$  in each of three axes at a maximum frequency of 1.27 cycles/sec.

Deployment of the drogue chute is a function of Mach number, acceleration, and angle-of-attack divergence, with the upper limit for deployment dictated by a velocity of Mach 2.0 which will occur at approximately 80,000 ft.

Assignment of a lower altitude limit for drogue deployment is dependent on the aerodynamic characteristics of the reentry shape and will require wind tunnel testing to firmly define; however, past experience indicates that a lower Mach number limit of approximately 0.8 which corresponds to an altitude of approximately 60,000 ft can be used as a first approximation.

## 5.9 SYNCHRONOUS RETURN REQUIREMENTS

Two basic methods of return were considered: (1) an elliptic transfer from synchronous to a parking orbit of 200 nm and then a normal EEOED return from the parking orbit, and (2) a direct descent from synchronous to the earth's atmosphere, and a pure ballistic reentry ( $L/D = 0$ ).

The former carries the penalty of 2-1/2 times the  $\Delta V$  as the direct descent method; however, it does not impose any difficult guidance or thrust control problems. The direct descent requires an order of magnitude greater accuracy and, in addition, requires a heavier heatshield to withstand the greater entrance velocity.

The use of a midcourse correction eliminates the need for extreme apogee accuracy but this necessitates onboard guidance operating throughout the 5-hr return because no ground tracking or assistance can be assured in the escape mode. In addition, the direct descent may offer limited recovery areas. An alternative to relieve the narrow reentry corridor is the use of a lifting reentry. This would require extensive redesign of the EEOED as the present configuration can only provide a maximum  $L/D$  of .1.

The weights for standard return propulsion packages are shown in Fig. 5-6 for both methods of return. The parking orbit method offers the advantage of operational capabilities of the low-earth orbit escape with the only modification to the EEOED being a possible improvement of guidance and control.

The direct descent requires increasing the heatshield by 450 lb and a sophisticated guidance package consisting of velocity meter, inertial guidance, and possibly a computer to provide the capability of midcourse corrections.

Component	Parking Orbit V = 12,690 fps		Direct Descent V = 5180 fps	
EEOED Weight	3000 lb		3450 lb	
Stage Guidance	20 lb		200 lb (midcourse correction)	
Stage Mass Fraction	.9	.8	.9	.8
*Propellant	11,200 lb	22,900 lb	2600 lb	2900 lb
Structure	1,260 lb	5,700 lb	280 lb	740 lb
Total Stage Weight	12,480 lb	28,620 lb	3080 lb	3840 lb
Total Gross Weight	15,480 lb	31,620 lb	6530 lb	7290 lb

\*Specific impulse = 305 (sec)  
UDMH -  $N_2 H_4 / N_2 O_4$

Fig. 5-6 Synchronous Return Weights

By redesigning the EEOED to accept a lifting reentry, the entry corridor could be opened up. The present design will provide an L/D = 0.1 by shifting the c.g. 7.5 in. This is not a significant improvement in that L/D in order of 0.3 to 0.5 is necessary to open up the allowable  $\gamma_E$  to 3 to 5 deg.

#### 5.10 GENERAL ARRANGEMENT, 6-9 MAN VEHICLE

The EEOED scaled up for use in a six- or nine-man escape mission and shown in Fig. 5-7, results in a vehicle with an estimated gross weight empty of 6,531 lb. With a nine-man crew, the weight at separation will be approximately 8,709 lb. The crew arrangement was developed with the objective of obtaining the most forward c.g. location and best crew ingress provisions. As with the three-man escape device, the majority of equipment is located in the forward section of the vehicle. The basic subsystem design for the nine-man escape device is essentially the same as the three-man vehicle with systems resized for the larger vehicle and crew conditions. Stability estimates for the vehicle indicate positive aerodynamic and flotation stability margins in both the forward and inverted conditions.

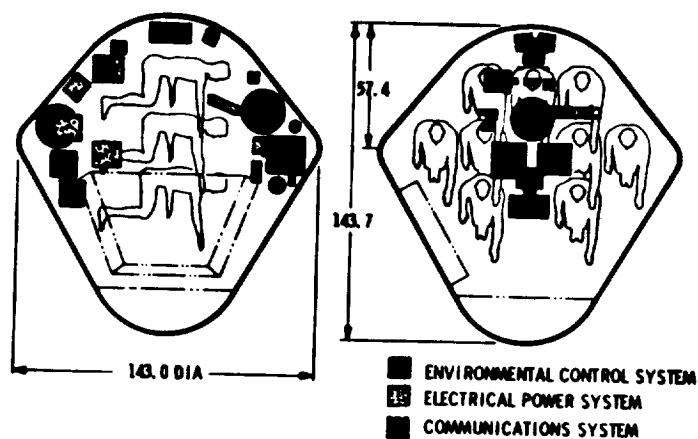


Fig. 5-7 General Arrangement 6 - 9 Man Mission

#### 5.11 EEOED DEVELOPMENT SCHEDULE

The development schedule calls for a 33-month span from Phase C go-ahead to launch of the first flight article from Kennedy Space Center. Any early freeze date on the structural, subsystem, and support equipment designs permits the evaluation of these designs early in the development cycle to allow the feedback of any required design changes before starting the flight vehicle fabrication. The major engineering span is completed simultaneously with the completion of flight vehicle final assembly. A lower level of sustaining engineering will then support the flight vehicle through acceptance, launch site checks, and flight operations. Test articles include a structural test vehicle, a drop test vehicle, a qualification test vehicle, and the first unit flight vehicle. The drop test vehicle could be modified for use as an interface checkout vehicle following completion of its test span. The acceptance test span includes complete systems level checkout of the flight vehicle followed by a final thermal/vacuum check prior to acceptance by NASA and shipment to the launch site.

#### 5.12 EEOED COST SUMMARY

The nonrecurring and first unit hardware costs are shown in Fig. 5-8; all costs are adjusted to 1970 labor rates and material costs.



Nonrecurring Costs. Design and development includes all engineering analysis, design, reliability, interface, and system engineering costs associated with the detailed design definition, development test, and qualification test of the escape system. All development and qualification testing can be performed at Lockheed's Sunnyvale complex except for the flight test program. The cost figures include a 10 percent contractor's fee allowance.

Recurring Cost - First Unit. First unit hardware cost includes materials and fabrication and assembly level of the flight hardware. All other costs such as system checkout and test, spares, publications, and sustaining engineering are included in the second cost item.

<u>Nonrecurring Cost</u>	<u>Millions of 1970 Dollars</u>
Design and Development	33.7
Test Program	42.5
Aerospace Ground Equipment	4.7
Sub Total	80.9
<u>Recurring Cost</u>	
First Unit Hardware	6.9
Sustaining Engineering, System Test, Spares, and Publications	6.7
Sub Total	13.6
Total Price (including fee)	94.5

Fig. 5-8 EEOED Cost Summary

### 5.13 SUMMARY

The EEOED Study effort has produced a conceptual vehicle design based on the results of parametric system evaluations of operational, aerodynamics, hydrodynamics, and human factor criteria.

In addition to the primary study effort of producing an escape vehicle capable of returning one, two, or three men from low earth orbit, the effects of modification of the device to accommodate a return from synchronous altitude and the scaling up of the vehicle to accommodate a nine-man low earth orbit escape was conducted.

A preliminary program definition plan for the basic three-man EEOED was prepared and forms a separate volume of the final report. The results of the study indicate the feasibility of the design concepts and would provide a simplified yet technically sound vehicle for use as an emergency escape device for current and future space missions.

## 6. STUDY LIMITATIONS

The basic task of the study was to define a conceptual design for a three-man escape device for use with a general class of earth orbiting space stations in the 100 to 300 nm altitude range. The groundrules and guidelines did not limit the accomplishment of this task. As they were based on the previous work done in this field, they provided a guide that helped restrict the study to the relevant considerations. The requirement to meet the worst case conditions for a wide range of orbits tends to produce a device that is somewhat overdesigned in the subsystem areas as compared to one that would be sized for a specific application such as AAP. However, these are variations which the basic concept can easily accommodate.

The lack of a specific mission or space station design limited the design effort in two areas; the definition of device/station interface details and the methods available for placing the device in orbit, e. g. can it be installed before launch or must a separate launch vehicle be used.

The completion of the normalization and comparison of alternate concepts task was seriously hampered by the lack of specific application details and the resources available. Besides considering the parameters of the escape device, a quantitative evaluation of overall effectiveness requires at least the definition of the spectrum of emergencies to be considered, and the crew location and state. All these are a function of the application. Secondly, most of these can only be described in terms of frequency distributions and associated probability density functions. Therefore, the resulting measure of system effectiveness is in the form of success probability distributions. The amount of effort required for this type of analyses was beyond the scope of the study.

## 7. IMPLICATIONS FOR RESEARCH

No basic research requirements have been established for the development of the escape device. Additional information on long orbital storage effects on subsystem components and materials is needed to obtain the five-year orbital storage goal.

The ability of the astronaut to perform the retro maneuver using manual attitude control and an optical reference system needs to be determined. Adequate optical reference systems particularly for nighttime firings have not been demonstrated. Although manual control of spacecraft attitude has been demonstrated during orbital flight, the loss in proficiency after long periods of time (in the order of months) has not been ascertained. It must be remembered that the escape mission is unique in that the astronaut must perform the retro maneuver within tolerances the first time. He does not get a second chance! Simulation runs made during the study showed the control was not difficult to obtain with a little practice, but the question of how well a subject can perform for the first time two months later was not answered.

#### 8. SUGGESTED ADDITIONAL EFFORTS

The combination of a firm set of system level mission requirements and the establishment of a firm design concept that meets the requirements means that a Phase C detail design definition phase can be started immediately.

Although acceptable solutions could be determined during design definition, studies and flight experiments could be performed in advance to enhance the design. One study would be the simulation of manual control of the escape device to determine optimum design parameters such as thrust-to-weight ratio, control authority, and performance degradation over periods of time. A second study would be to evaluate the overall escape system effectiveness for a particular mission and space station design.

A study and flight experiment could be performed to analyze and prove out the technology of an optical sighting device with image intensification for use by the command astronaut during retrorocket operation as a reference system. Such a program would involve its use by the astronaut on both the earth light and dark side and during the firing of retro-type solid rockets to check out the effect of rocket plume on the astronaut's sighting ability. Additional candidate devices could be analyzed and checked out, resulting in a firm choice of the proper sighting system for the escape system.